

Equipment Grant

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE October 19, 1994	3. REPORT TYPE AND DATES COVERED Final Technical Report Sept. 1, 1993-Aug. 31, 1994		
4. TITLE AND SUBTITLE Power Measurement and Current Feedback in a Resonant DC Link Inverter		5. FUNDING NUMBERS F49620-93-1-0534 61102F 3484/BS		
6. AUTHOR(S) Dr. Subbaraya Yuvarajan				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) North Dakota State University P.O. Box 5790 Fargo, ND 58105 - 5790		8. PERFORMING ORGANIZATION REPORT NUMBER AFOSR-TR- 95 0118		
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) AFOSR /NE 110 Duncan Avenue Suite B115 Bolling AFB DC 20332-0001		10. SPONSORING / MONITORING AGENCY REPORT NUMBER F49620-93-1-0534		
11. SUPPLEMENTARY NOTES		19950323 156		
12a. DISTRIBUTION / AVAILABILITY STATEMENT XXX APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED				
13. ABSTRACT (Maximum 200 words) Resonant dc link (RDCL) inverters employ zero-voltage switching to reduce switching loss in power converters and to improve their efficiency. The project uses current feedback to eliminate zero-crossing failure in RDCL inverters. The zero-crossing failure is corrected by sensing the load current and feeding it back to control the operation of the link-shorting switch. The operation of the control scheme is first established by simulating the converter using computer simulation. The current feedback is implemented on an experimental RDCL inverter. The inverter is built using current-sensing Power MOSFETs that provide signals proportional to the current. The control signals to the inverter switches and the outputs from the current sensing MOSFETs are fed back to control the frequency and the duty cycle of the input to the link-shorting switch. The addition of proper level of current feedback is found to reduce the minimum link voltage to zero. The waveforms of the link voltage with and without current feedback are recorded and studied using a digital storage oscilloscope. The power loss in the RDCL inverter is also computed using the oscilloscope and it is seen the addition of current feedback results in a higher efficiency for the converter.				
14. SUBJECT TERMS Resonant DC Link Inverter; Switching loss; Current Feedback		15. NUMBER OF PAGES 4		
		16. PRICE CODE		
17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT	

FINAL TECHNICAL REPORT

AFOSR-TR- 95 0118

Grant No.: F49620-93-1-0534

Title: Power Measurement and Current Feedback in a Resonant DC Link Inverter (DEPSCoR 92)

Period: Sept.1, 1993 - Aug. 31, 1994

Project Type: DoD - EPSCoR Research Equipment Grant

Principal Investigator: Dr. Subbaraya Yuvarajan
Electrical Engineering Department
North Dakota State University
Fargo, ND 58105

Equipment Actually Acquired:

1. **Digital Storage Oscilloscope** (with 4 channels, 20 MS/sec, 12 bit, 1 Mbyte/channel) and FAMOS software for waveform analysis.

Manufacturer: Nicolet Instruments Inc.
5225 Verona Road
Madison, WI 53744-4451

Price: \$37,405

2. **Current Probe** (100 A with 50 MHz bandwidth)

Manufacturer: Tektronix, Inc
P O. Box 4600
Beaverton, OR 97076

Price: \$3,387

Accession For	
NTIS CRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

3. DC Power Supply (33 A, 0 - 300 V)

Manufacturer: Sorenson Co.
615 N. Railroad Avenue
Paxton, IL 60957 - 1006

Price: \$4,681

4. Personal Computer (Pentium 90 MHz)

Manufacturer: Gateway 2000
610 Gateway Drive
North Sioux Falls, SD 57047-2000

Price: \$4,020

5. Laser Printer (Laserjet 4)

Manufacturer: Hewlett Packard

Price: \$1,282

6. Memory for Laser Printer (8 Mbyte)

Manufacturer: Hewlett Packard

Price: \$374

7. Memory for PC (4 Mbyte)

Manufacturer: Nevada Computers

Price: \$179

Total cost of equipment bought: \$51,328

Grant from AFOSR: \$45,000

Match from North Dakota State University: \$6,328 (12.33%)

Changes to the Equipment List Originally Proposed:

The isolation probe with optical link (Item #3) and the DSP evaluation board (Item #5) in the original list were made available for the project from other sources.. On the other hand, a good dc power supply was needed to supply the resonant dc link. A high speed personal computer and a printer with enhanced memory were needed to simulate the current feedback in the resonant dc link and to print the output waveforms, respectively. All the three items were actually purchased for the successful completion of the project. The manufacturers of the digital oscilloscope and the current probe offered educational discounts which reduced the actual purchase price. The educational discounts received from the manufacturers and the additional funding provided from the department helped to limit the total expenditure within the proposed budget amount.

Summary of Research Projects (for which the Equipment has been used):

1. Development of a Resonant DC Link Inverter with Current Feedback

Resonant dc link (RDCL) inverters employ zero-voltage switching to reduce switching loss in power converters and to improve their efficiency. The project implements a novel control scheme to overcome the zero-crossing failure in an RDCL inverter, using current feedback. The zero-crossing failure which is caused by a change in the load current is corrected by sensing the load current and feeding it back to operate the link-shorting switch. The control scheme was first simulated using the software PSPICE on the high-speed personal computer (Pentium 90). The effect of current feedback in reducing the minimum link voltage and stabilizing the RDCL was established.

The current feedback was implemented on an experimental inverter with current sensing MOSFETs as the power switches. The RDCL was fed from the variable-voltage dc power supply. The PWM control signals to the inverter switches and the current feedback signals from the current sensing MOSFETs were used to control the frequency and the duty cycle of the input to the link-shorting switch. The addition of current feedback was found to improve the link voltage. The waveforms of the link voltage with and without current feedback were recorded and studied using the digital storage oscilloscope purchased for the project. The oscilloscope was also used to record the waveforms of the current and voltage input to the RDCL inverter and compute the power accurately. It was possible to show quantitatively that the current feedback enables zero-voltage switching thereby reducing the power losses in the link as well as the inverter. The project also studied the effect current feedback-gains on the performance of the RDCL inverter.

2. DC-DC Power Conversion Using A Resonant Link

The equipment purchased from the grant money were also used to develop a dc-dc power converter operating from a dc link. The RDCL developed for the previous project supplied power to a four-quadrant dc chopper. The output of the chopper was varied by varying the duty cycle of the control signal to the four switches. The switches in the dc chopper were made to turn-on and turn-off at zero voltage thereby keeping the switching loss minimum. The control circuit used a staircase waveform generator along with a discrete level comparator to provide zero-voltage switching and variable duty cycle simultaneously.

The experimental converter was built and tested. Since the converter switches operate at zero voltage, they did not require any snubber. Zero-voltage switching does not result in any electromagnetic emissions (EMI). The waveforms were recorded using the digital storage oscilloscope. The harmonic content in the output waveforms were obtained using the waveform-analysis software FAMOS. The frequency spectrum of the load current contains fewer harmonics compared to the frequency spectrum of the load voltage. The component at the resonant frequency (100 kHz) had negligible effect on the output.